



***DARPA*Tech**

2002 Symposium

Transforming
Fantasy



Clark Nguyen

Program Manager

Microsystems
Technology Office



Micro Electro Mechanical Systems Programs at MTO

Clark T.-C. Nguyen
Program Manager, DARPA/MTO



Microsystems Technology Office

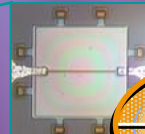
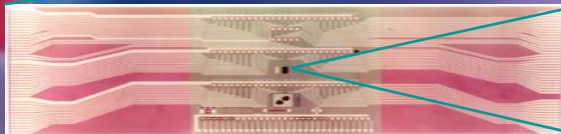


Technology for Chip-Level Integration of E. P. M.



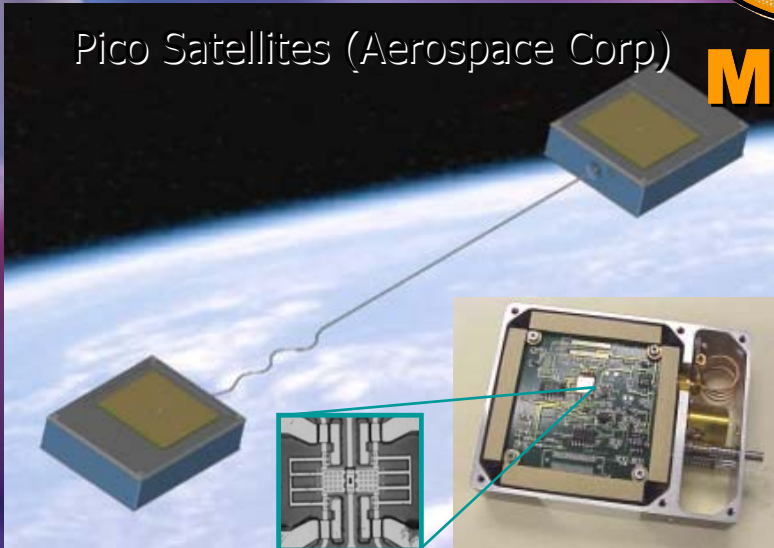
MEMS Application Domains

Shear-Stress Sensor for Jet Fighter (Caltech)



M E M S

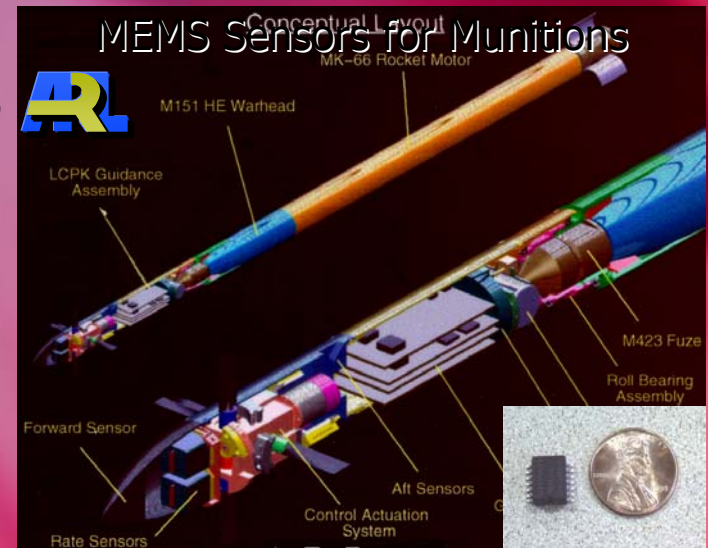
Pico Satellites (Aerospace Corp)



MEMS Exploder for Torpedoes

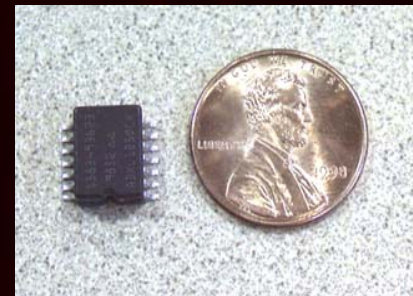
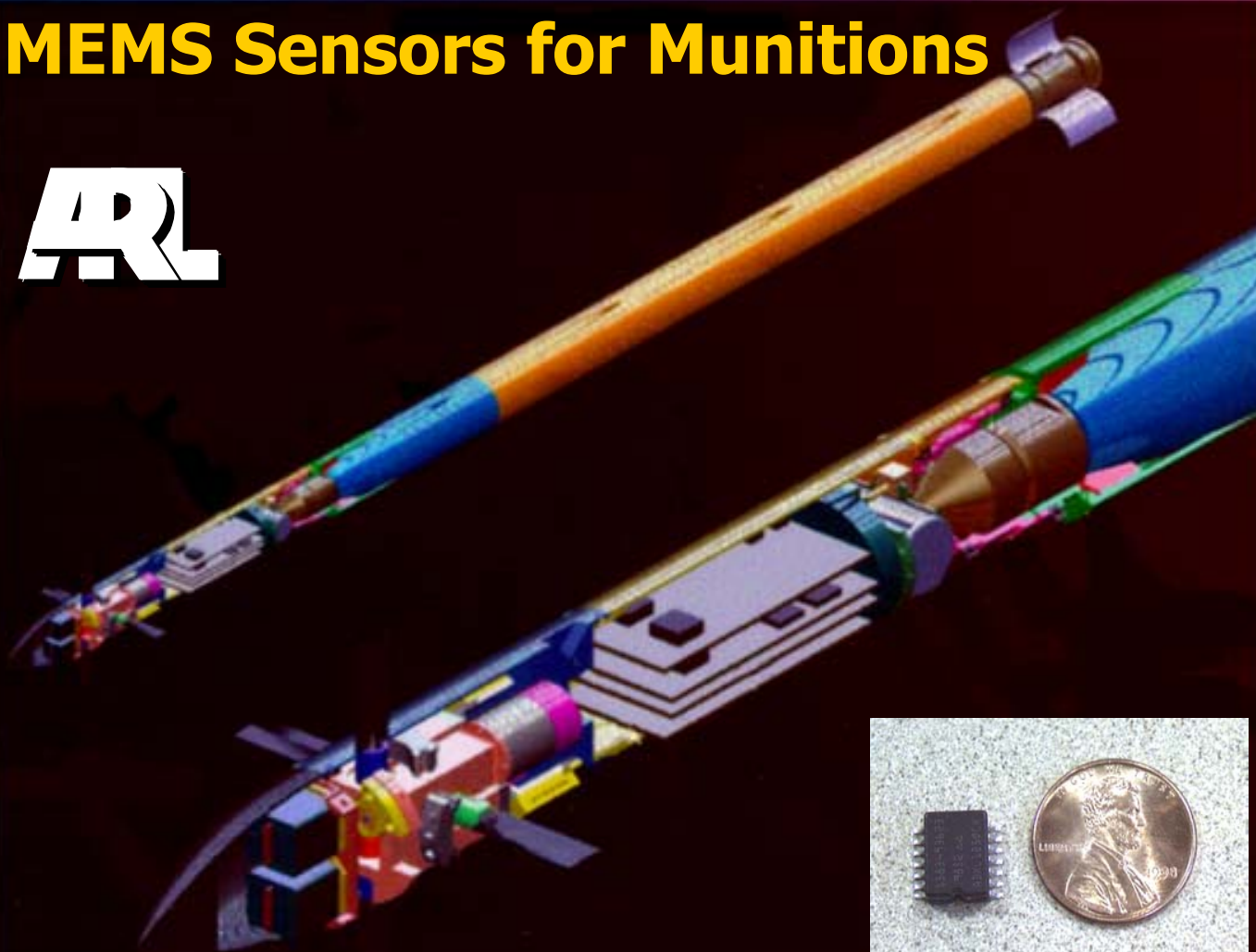


MEMS Sensors for Munitions



Land Applications of MEMS

MEMS Sensors for Munitions



Sea Applications of MEMS

MEMS Exploder for Torpedoes



Sea Applications of MEMS

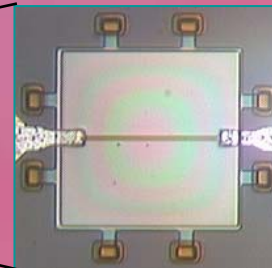
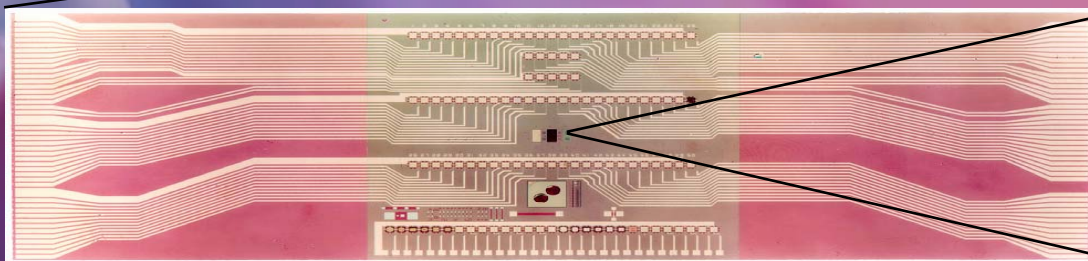
MEMS Exploder for Torpedoes



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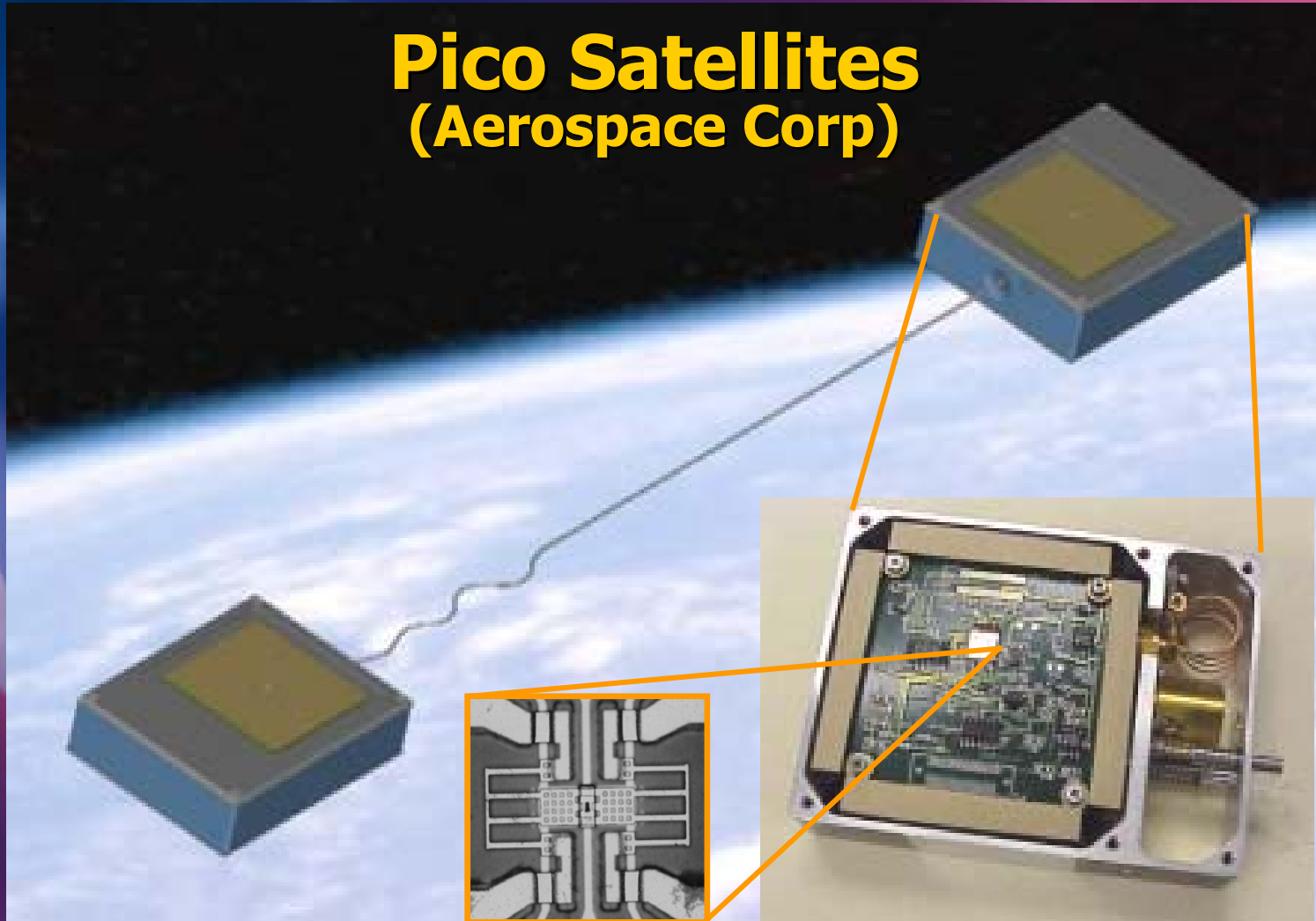
Air Applications of MEMS

Shear-Stress Sensor for Jet Fighter (Caltech)



Space Applications of MEMS

Pico Satellites (Aerospace Corp)

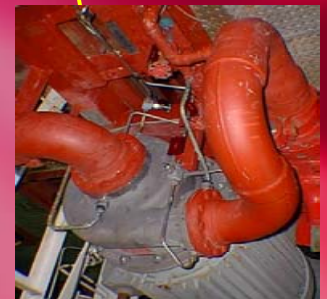
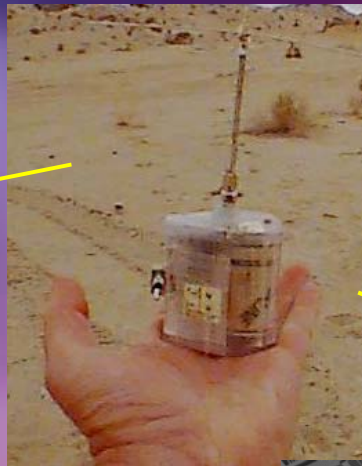


Wireless Integrated Sensors

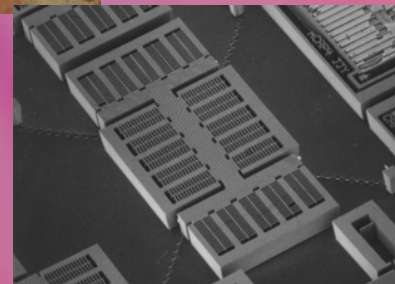
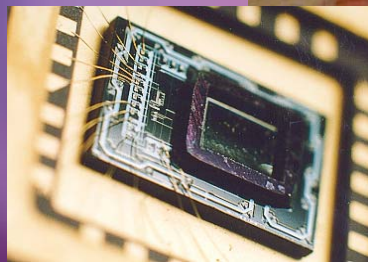
- ▶ Allow remote maintenance, health monitoring, and environmental monitoring



**Army NTC /
Aberdeen PG**



USS Rushmore

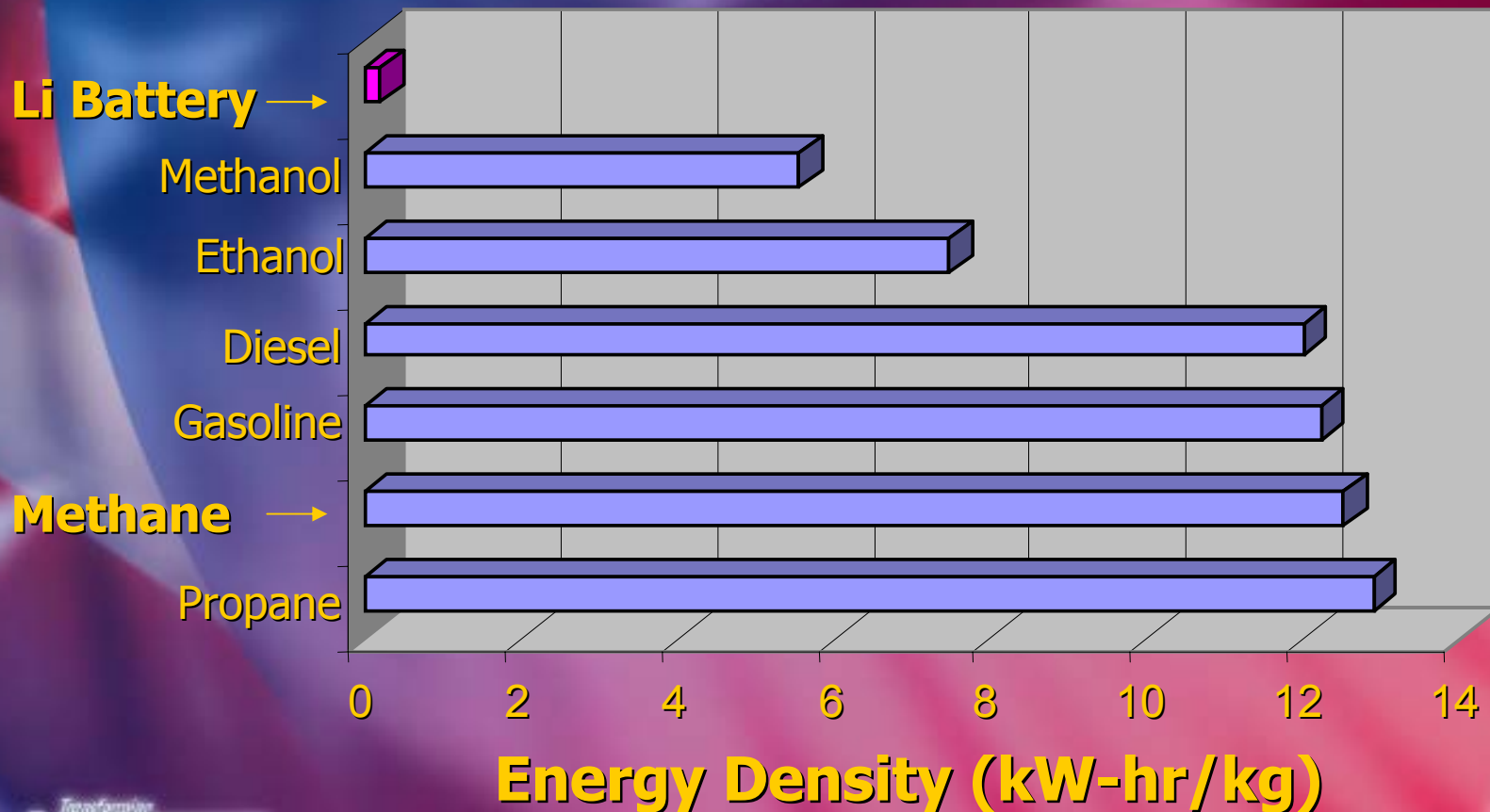


Integrated Sensors



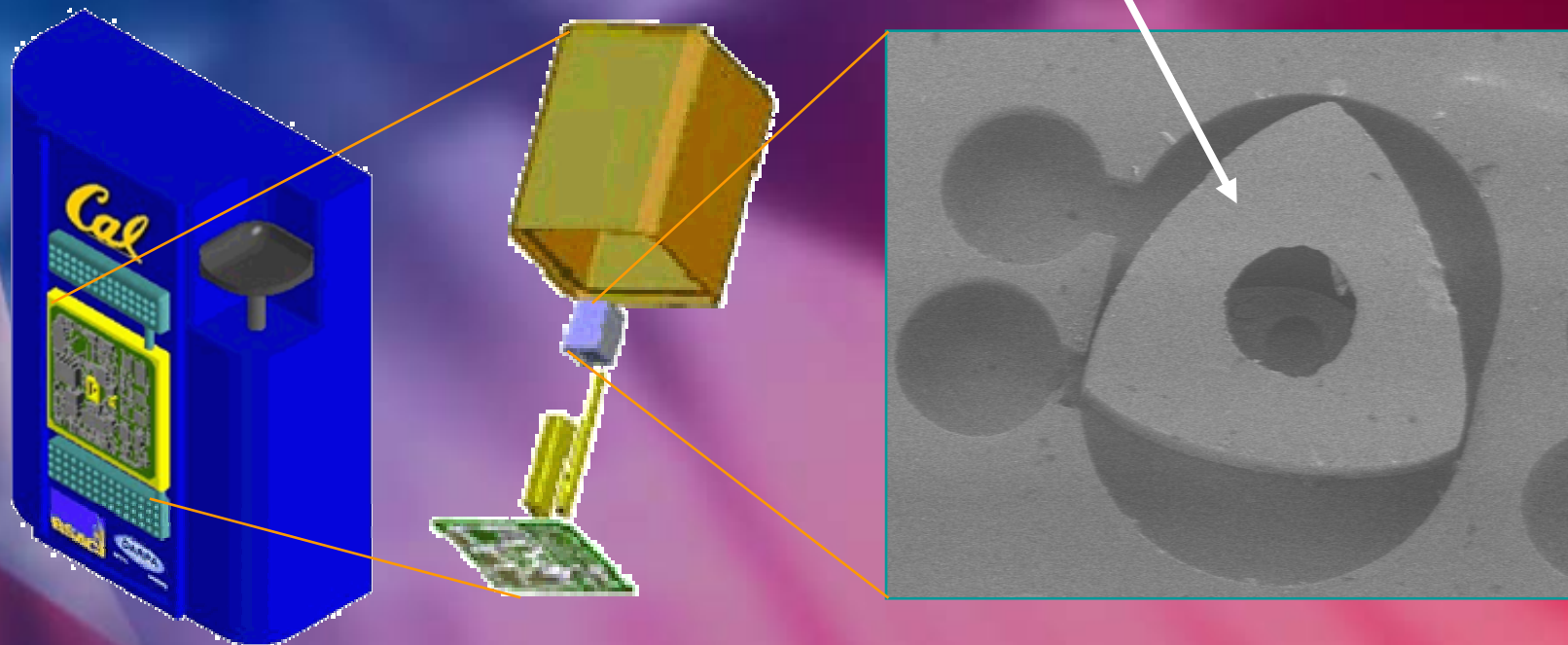
Micro Power Generation

- Harness fuels with higher energy density



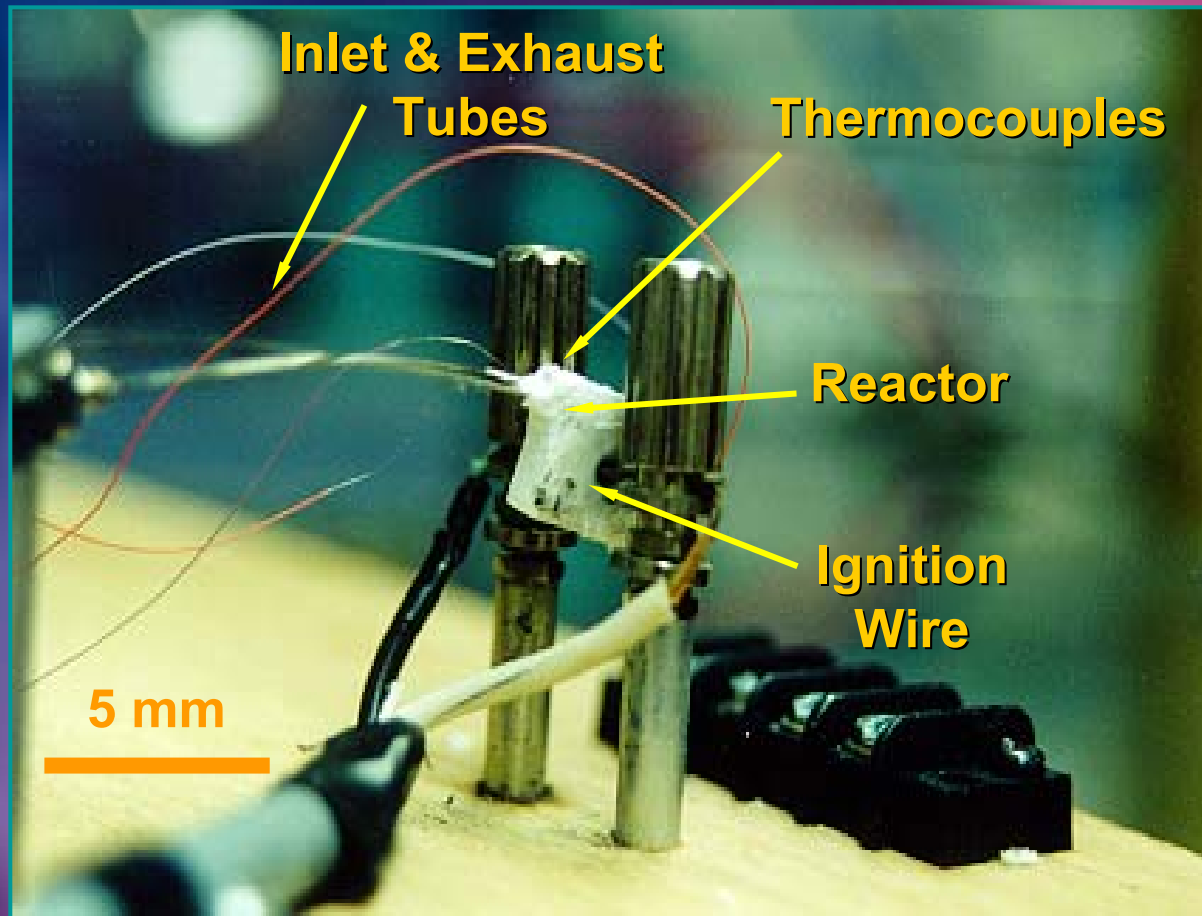
Micro Rotary Engine

Micro Rotor



[University of California at Berkeley]

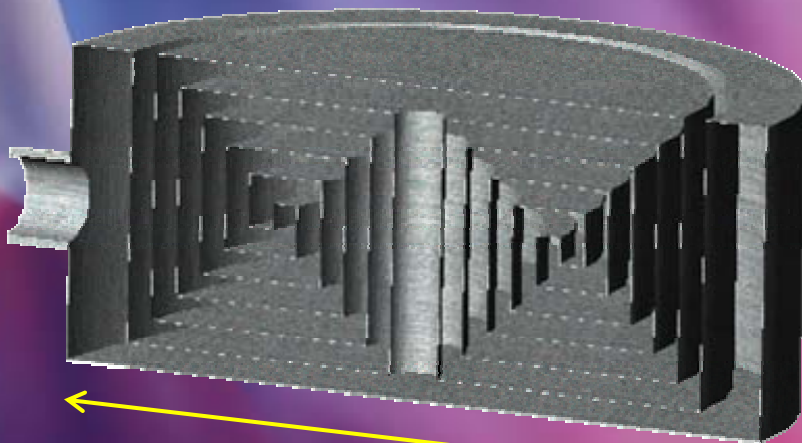
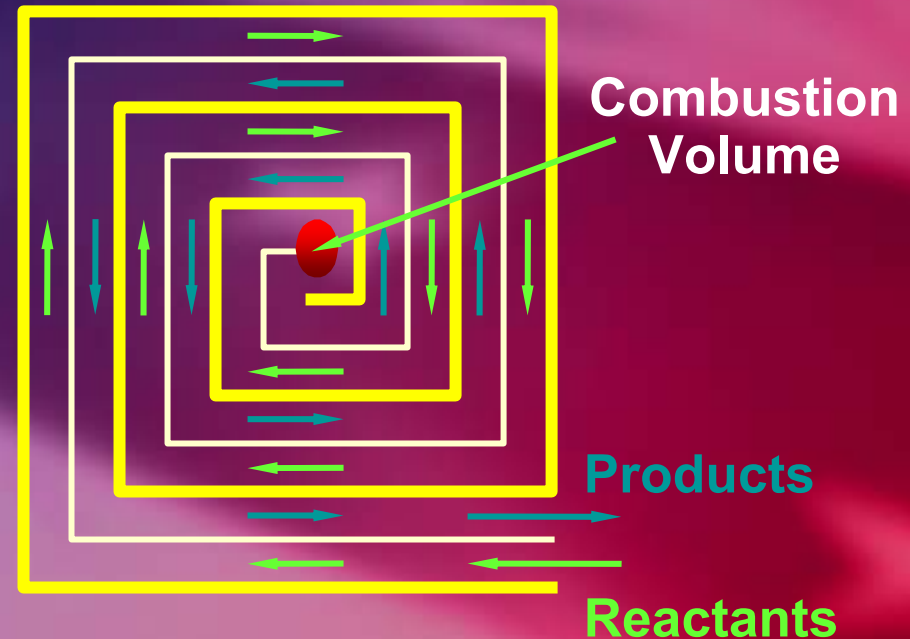
Micro Combustion Chamber



Alumina reactor with 200- μ m-wide Pt-coated square channels [Princeton]

Thermoelectric Combustion

- ▶ Maximize thermoelectric surfaces between hot and cool regions

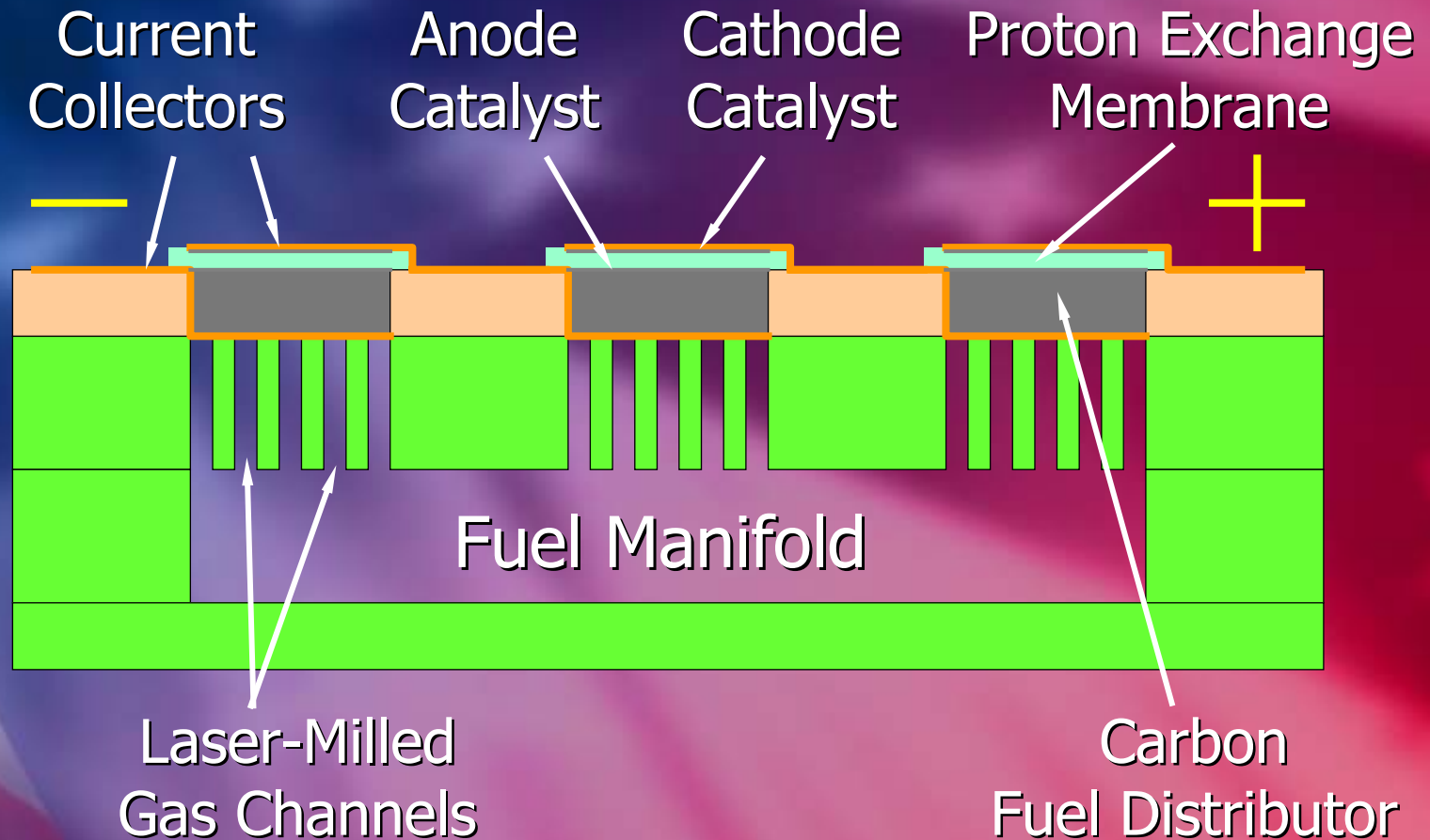


~ 5 mm

**3-D Toroidal Swiss-Roll
Microcombustor/Generator
[Univ. of Southern Cal.]**



Micro Fuel Cell

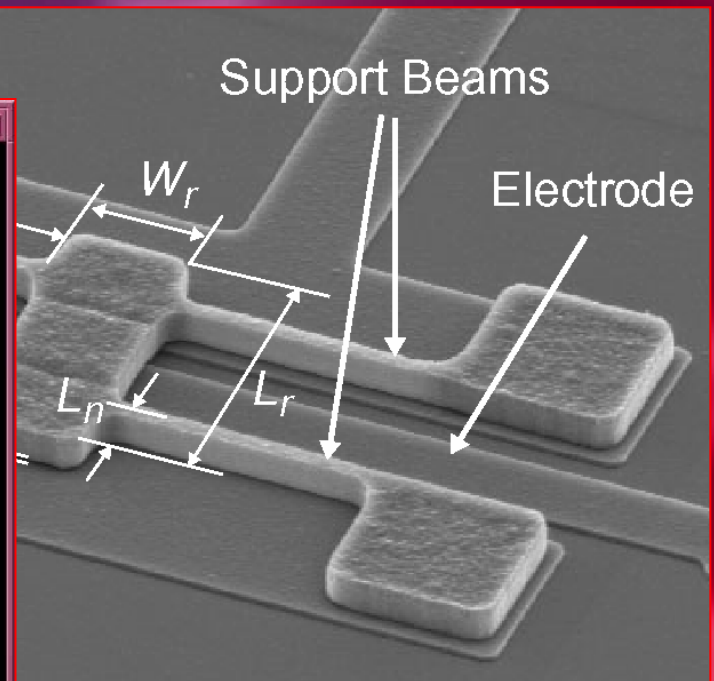
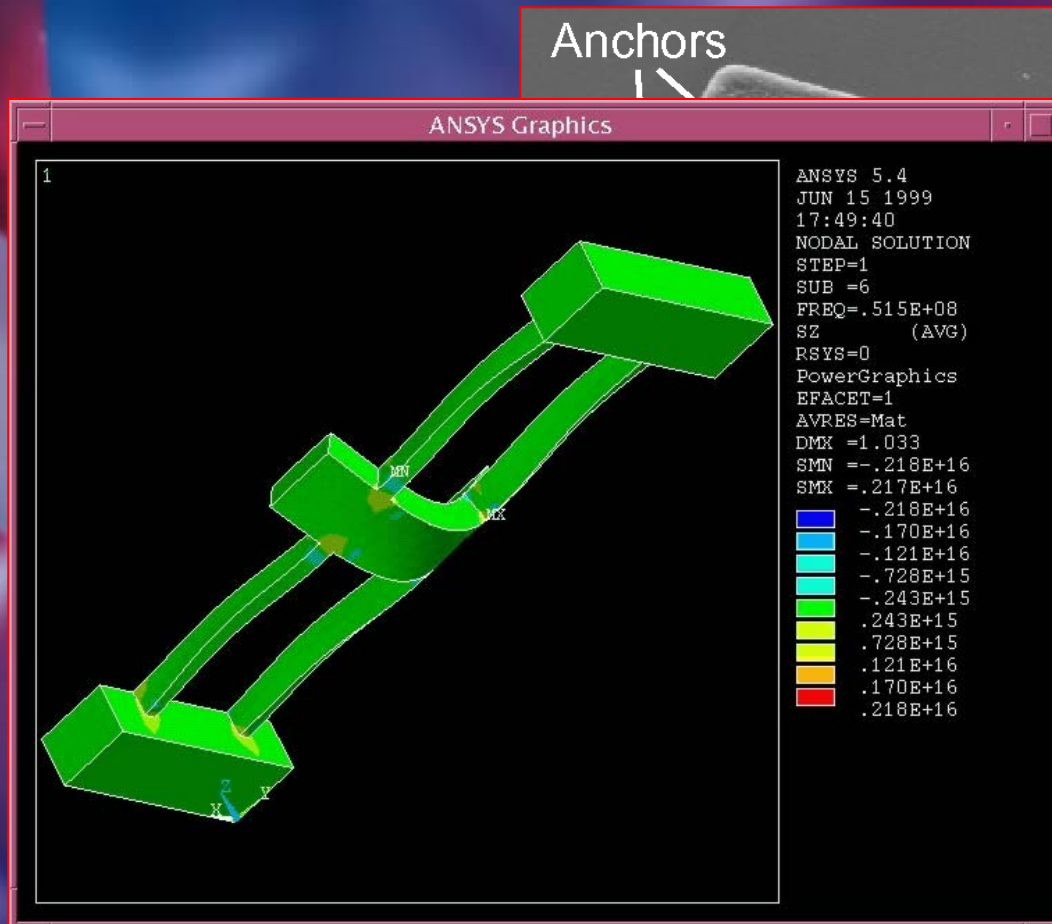


Micro Fuel Cell
[Case Western Reserve Univ.]



Nano Mechanical Array Signal Processors

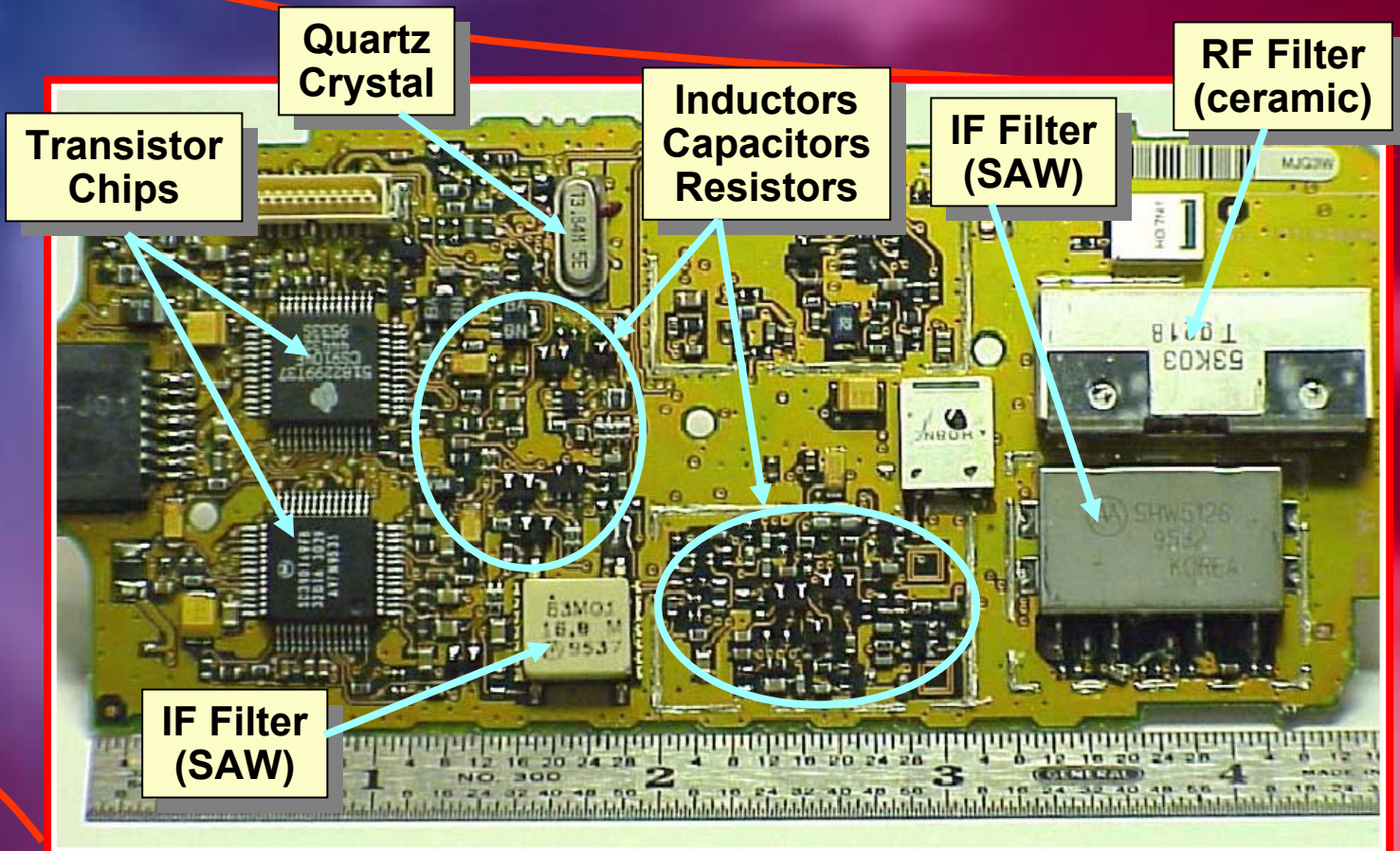
>100X reduction in size and power consumption over conventional frequency processors



**Free-Free Beam Vibrating
Micromechanical Resonator
[University of Michigan]**

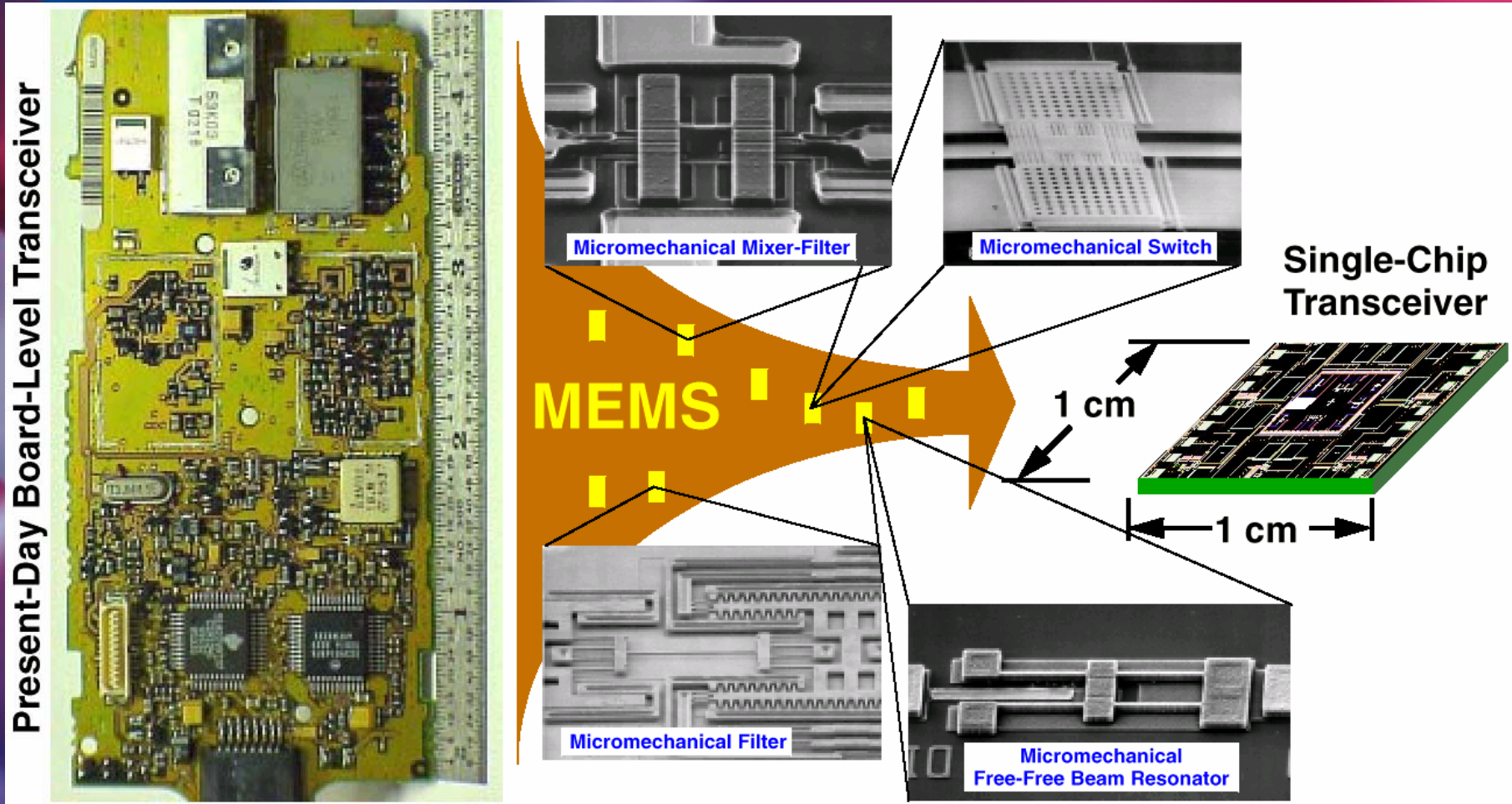
So Many Off-Chip Passives

Passives pose a bottleneck against miniaturization of wireless handsets



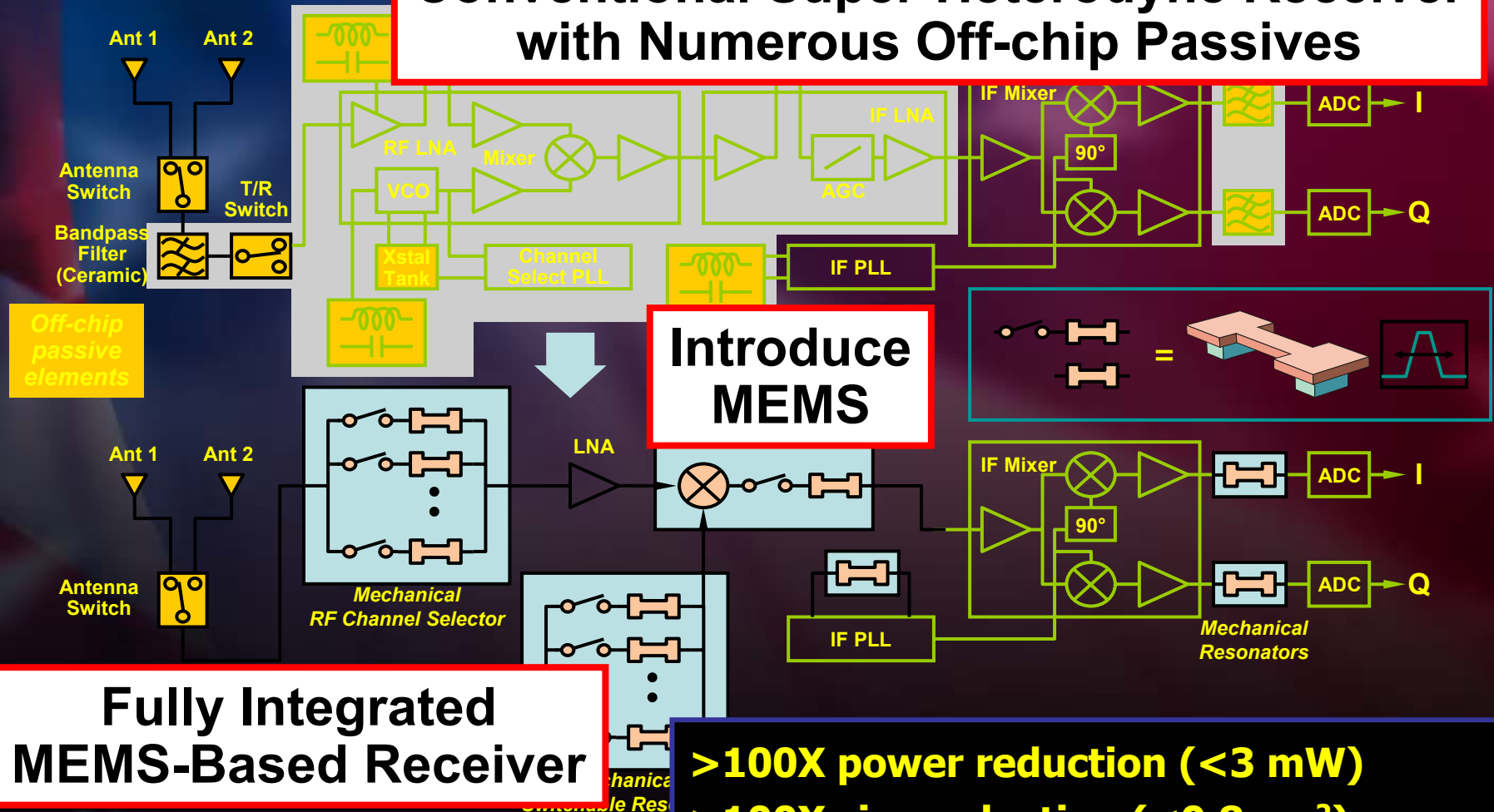
Miniaturization of Transceivers

- Replace off-chip passives with MEMS



MEMS-Based Receiver Blocks

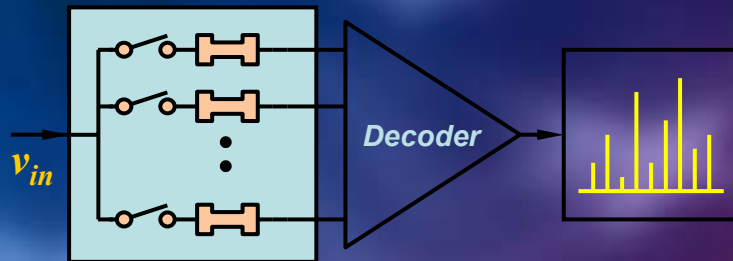
Conventional Super-Heterodyne Receiver with Numerous Off-chip Passives



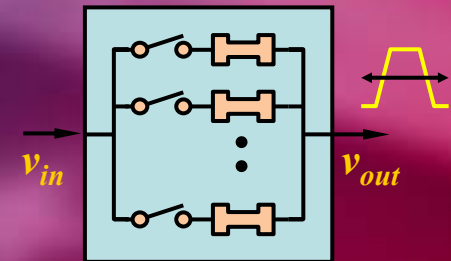
- >100X power reduction (<3 mW)
- >100X size reduction (<0.8 cm²)
- >10X improvement in spectral eff. & BW



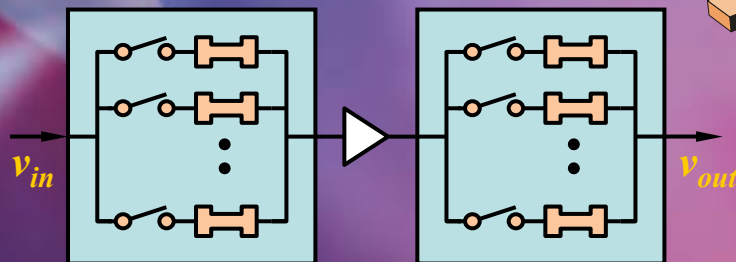
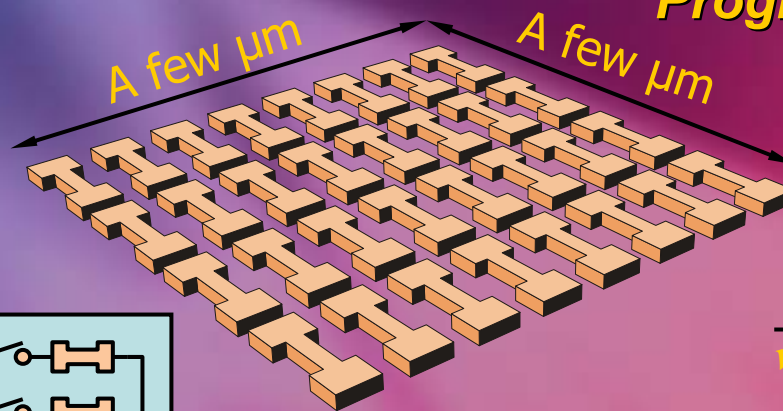
Large Arrays of Micro Resonators



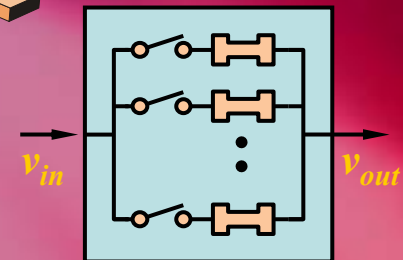
**Spectrum Analyzer /
Fourier Signal
Transformer**



**Tracking Filter /
Discriminator /
Programmable Equalizer**

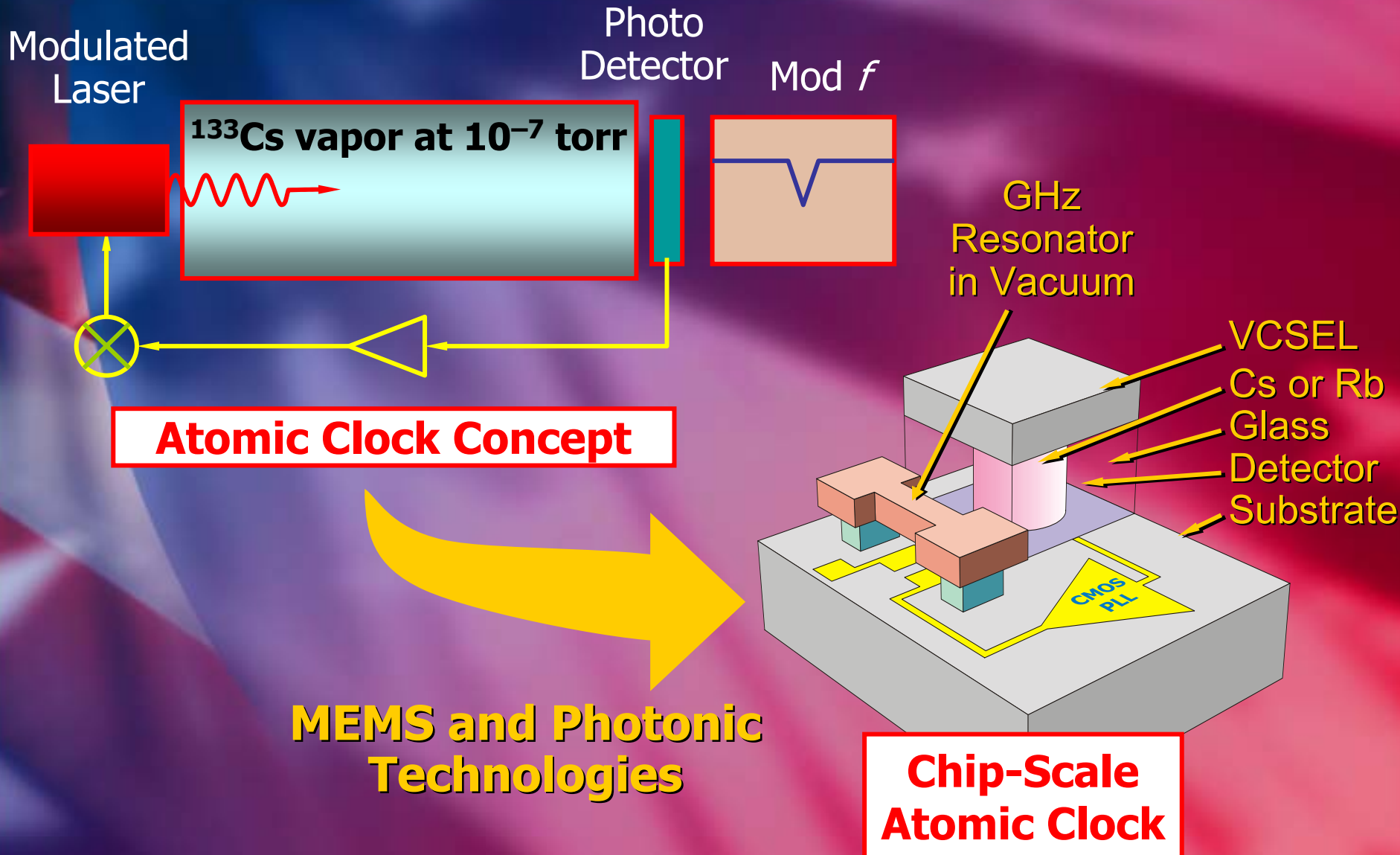


Frequency Converter

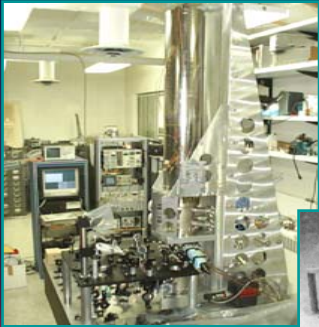


**Parametric Amplifier /
Digital Demodulator /
Envelope Detector**

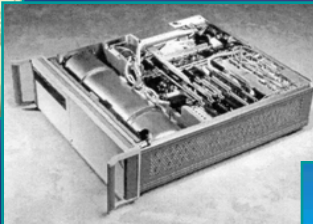
Chip-Scale Atomic Clocks



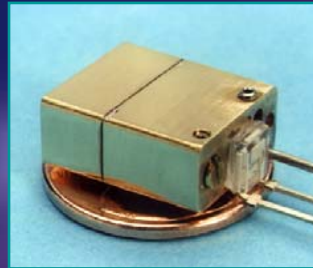
Miniaturization of Atomic Clocks



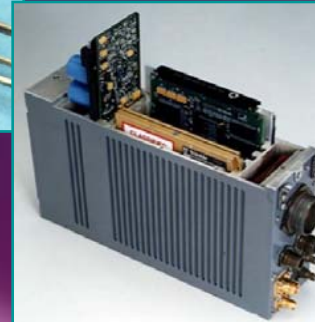
NIST- F1



HP 5071A



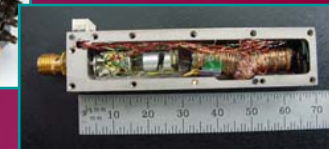
NG MC250



Kernco



Datum R2000



NIST CPT cell



Temex RMO



CSAC

Vol: $\sim 3.7 \text{ m}^3$
Power: $\sim 500 \text{ W}$
Acc: 3.8×10^{-15}

State-of-Practice

State-of-Research

Vol: 1 cm^3
Power: 30 mW
Acc: 1×10^{-11}

CSAC-Enabled Enhancements

- ▶ High channel selectivity and enhanced channel density for VHF/UHF comm.



- ▶ Better resilience against jamming
- ▶ Extended silence in radios



SINCGARS Radio



CSAC's Applied to Navigation

- Direct P/Y-code acquisition – fast acquisition at low power
- Missile and munitions guidance – g-hard precision clocks

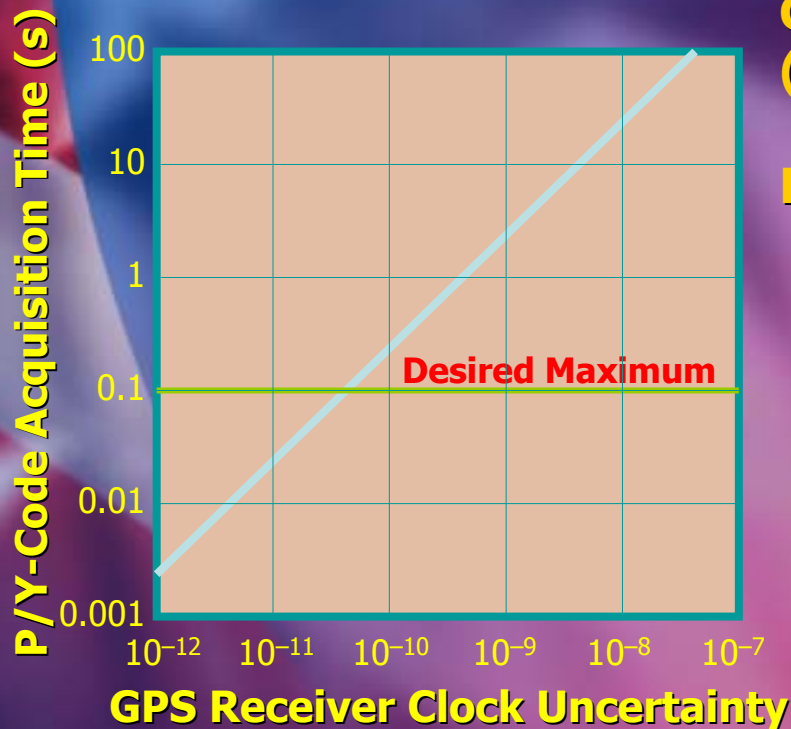
Examples of Use:

GPS Position Location Reporting System (GPS PLRS)

- Fielded units: ~100,000 & growing

Future Joint Tactical Radio System (JTRS)

- Potential fielding: ~300,000 (FY10)



9,000 commercial handheld GPS deployed in Desert Storm



M

Z-axis Gyroscope

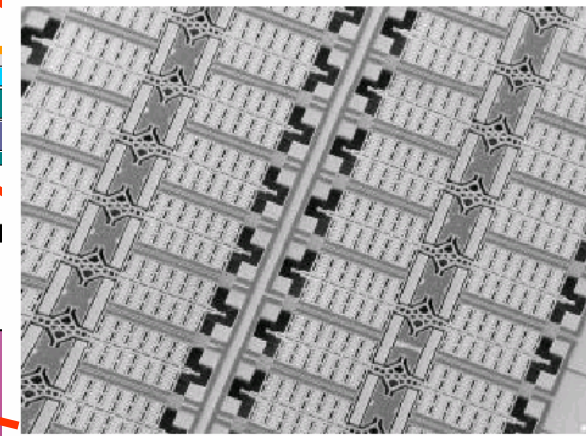
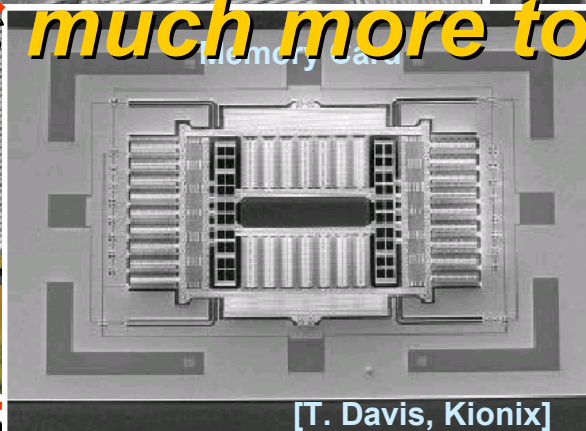
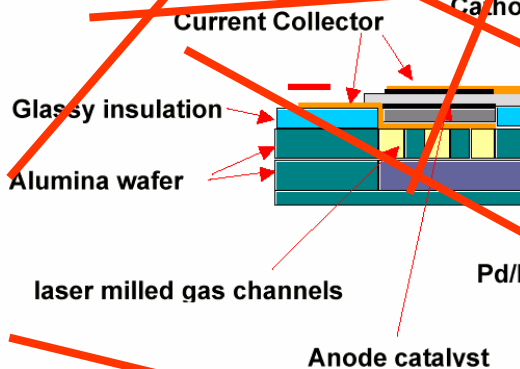
Technology
Vibration Detection System

...and there is much more to be done...

[B. Boser, UC Berkeley]

- 5 mm x 5 mm
- laser machine

Spa



Fabrication
techniques

Bias board

board

rd]
0 μm

6 psi
15 psi
10 μm

Sensor



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